HISTOLOGICAL AND MICRORADIOGRAPHICAL STUDIES OF HUMAN MANDIBULAR CONDYLE

BY

Hong-Yea Lin, Akira Komori and Goro Ishikawa*1

Abstract

Twenty-one clinically normal human mandibular condyles were examined by histologic and microradiographic methods obtaining some measurements. The histological structures of condyle were quite different between the child group and other aged groups. The difference in the surface articular zone composed of the fibrous tissue was not so great in all age groups, while there was quite a difference in the structure in the remaining zones. It was clearly demonstrated by microradiogram that the oscons of the subarticular bone plate were more prominent in aging. Abnormal structures of the condyle were revealed in some individuals of the adult and old age groups, which were assumed probably to be the reactive remodelling against the functional changes of the temporomandibular joint.

Introduction

The anatomy and the growth and development of the human temporomandibular joint have been studied by several investigators. The normal structure of the human condyle has been reported by Morinaga (1940, 1941, 1942),1) Moffett et al. (1964),2) Iida (1972),3) Ishibashi (1972),4) Wright and Moffett (1974),5) Thilander et al. (1976) and Ingervall et al. (1976).6) The articular surface of the temporomandibular joint is normally not composed of the hyaline cartilage usually found in most joints. Certainly, several physioanatomic characteristics and the functional complexity of the temporomandibular joint differed definitely from the other articulations. Their normal physioanatomical characteristics were always closely bound with the clinical management. Therefore, active investigations were made from the latter half of this century to find the real special features of the temporomandibular joint that may modify its response to some pathological process, which forms the basis for clinical practice, etc. However, many of the investigations used experimental animals and for the wide range of age there was little histological study of the human mandibular joint to obtain detailed information in order to understand about the joint disease. In this paper will be presented the histological and microradiographical observations on twenty-one human mandibular condyles between the age of 1 and 70.

Materials and Methods

Materials were composed of 21 left human mandibular condyles of both sexes between the age of 1 and 70. Of the 21, two condyles were taken from the operated materials which was removed for oral

*1 林 宏麿, 小守 講, 石川隆明: Department of Oral Pathology. (Chief: Prof. G. Ishikawa), School of Dentistry, Tokyo Medical and Dental University (Tokyo Ika Shika Daigaku).
Received for publication, November 2, 1977.
carcinoma without discomfort to the temporomandibular joint. The remaining 19 were taken by routine autopsy at random, which had no temporomandibular disorder clinically. Of the cadaver, prior to the condyle removal, the dentition was briefly examined but the details were not available. There was no case wearing complete denture. The condyle processes were cut through the mandibular neck and were fixed in 10% neutral buffered formalin. They were x-rayed by the antero-posterior and lateral-oblique projections after the removal of the articular disc. The median sagittal section was made for each condyle. The halves of the condyles were used for the paraffin sections after decalcification by Plank-Rychlo's method under a constant temperature of 4°C. The paraffin sections were stained with hematoxylin-eosin, alcian blue and elastica van Gieson's solution. The remaining halves were used for the ground sections embedded in the Rigolac resin. Materials embedded in resin were cut with a thin-sectioning machine and polished to a thickness of 100 μ. The contact microradiogram of these ground sections were made on the spectroscopic plate Type 649-0 (Kodak Co.) using the x-ray diffraction generator Type PW-1008 (Philips Co.).

One H. E. specimen from the median of the condyle was selected for measuring the thickness of the articular tissue (from the surface to the junction between hypertrophic and bone formation zones) and the subarticular bone plate. The specimen was divided into three parts, i.e., anterior, posterior and superior, by trisecting through the mid-point of the line between the lower margins of the anterior and posterior slopes opening towards the joint surface. Ten sites approximately of equal interval were taken for each V-shaped part and 30 sites in total per each condyle for the measurement. One microradiogram made from the middlemost ground section was used for the measurement of the osteons of the subarticular bone plate.

**Results**

For the description of the histological findings, the individuals were divided into four age groups: child group (1, 9 and 15 years), young adult group (26, 27 and 27 years), adult group (37, 47, 49, 50, 55, 56, 57 and 59 years) and old age group (60, 61, 63, 70 and 70 years).

Histologically, usually four layers can be seen in the condyle, i.e. the surface articular zone, proliferative (or intermediate) zone, hypertrophic zone and bone formation zone (Fig. 1).

The observations on each age group were as follows:

1) Child group: The surface articular

---

**Fig. 1. Articular Tissue of Mandibular Condyle Composed of Four Distinct Layers, S: surface articular zone, P: proliferative zone, H: hypertrophic zone, B: bone formation zone. A 9-year-old girl. H.E. x120**
zone was composed mainly of collagen fiber bundles arranged approximately in parallel to the surface. The proliferative zone was relatively narrow and highly cellular. The cells were small in size and closely packed together. There were only a small amount of intercellular substance. The inferior border of the proliferative zone transferred gradually into hypertrophic zone. The hypertrophic zone was made up of enlarged chondrocytes embedded in the matrix. In the deeper layer of the hypertrophic zone, mineralization of the matrix occurred and it continued to the bone trabeculae of the bone formation zone (Fig. 2). Microradiographically, irregular mineralization appeared as fine anastomosing radiopaque figures in the lower part of the hypertrophic zone. The mineralized cartilage continued to the radiopaque trabeculae in the bone formation zone (Fig. 3).

2) Young adult group: The surface articular zone was composed of collagen fiber bundles like in the child group. The proliferative zone had more or less become narrow though it appeared as closely gathered small cells. The larger portion of the hypertrophic zone had been converted into a hyalinized fibrocartilage tissue. The chondrocytes in the matrix decreased remarkably as compared to that of the condyles in the child group. They also varied in size and the larger ones were located in the deeper layer. The bone formation zone formed a bone plate composed of the lamellar compacted bone adjacent to the hyaline cartilage of the hypertrophic zone. The bone trabeculae extended from the bone plate to the marrow space (Fig. 4). Microradiographically, irregular mineralization, which was more radiopaque than that of the bone plate, was observed in the deepest area of the hyaline cartilage layer in the hypertrophic zone. The structure of the osteons was identified in the bone plate of the bone formation zone (Fig. 5).
Fig. 4. Articular Tissue of Mandibular Condyle in the Young Adult Group. Note the composition of the fibrocartilage tissue in the hypertrophic zone and bone plate in the bone formation zone. A 27-yr-old female H.E. ×50

Fig. 5. Microradiogram of the Same Subject as in Fig. 4. This figure shows the bone tissue in the bone formation zone. ×50

Fig. 6. Articular Tissue of Mandibular Condyle in the Adult Group. Note the disappearance of the proliferative zone and thinning of the hypertrophic zone. A 57-year-old male H.E. ×50

Fig. 7. Microradiogram of the Same Subject as in Fig. 6. This figure shows the bone structure with osteons in the bone plate. ×50

3) Adult group: The surface articular zone was composed of a more dense fibrous tissue. The proliferative zone had almost disappeared. The hypertrophic zone was made up of a more hyaline fibrocartilage and the chondrocytes were more decreased in number. A few chondrocytes were located only in the deepest area. Adjacent to the hyaline cartilage of the hypertrophic zone, there was a bone tissue composed of a dense lamellar bone in the bone formation zone. Thick bone trabeculae also extended from the bone plate to the marrow space (Fig. 6). Microradiographically, the osteons were observed distinctly in the
bone tissue of the bone formation zone. The superficial part of the bone formation zone was more radiopaque (Fig. 7).

In this group, the histological details of the articular tissue varied individually, and abnormal structures were observed in some subjects. In three cases, the junctional area between the hyalinized fibrocartilage and the bone plate beneath it was irregular

with a few scattered chondrocytes in the hyaline cartilage on the anterior slope of the condyle (Fig. 8). A depression of the articular tissue was observed at the crest of the condyle in three cases. In these
areas, the surface articular, proliferative and hypertrophic zones had disappeared, and the surface of the bone plate was covered by a fibrous tissue (Fig. 9). In one case, granulation tissue and bone resorption were seen in the depressed area at the crest of the condyle (Fig. 10). An irregular proliferation of the bone tissue with a few chondrocytes was observed on the surface of the anterior slope in one case (Fig. 11).

4) Old age group: The surface articular zone was composed of a dense fibrous tissue. The proliferative zone had almost disappeared. The hypertrophic zone was also extremely narrow and made up of hyaline fibrocartilage. The chondrocytes had almost disappeared in the hypertrophic zone. The bone plate of the bone forma-
Histology of Human Mandibular Condyle

Fig. 16. Depression of Bone Tissue at the Crest of Condyle in the Old Age Group. A 63-year-old female H.E. ×50

Fig. 17. Irregular Resorption of Bone Plate at Posterior Surface in the Old Age Group. A 63-year-old female H.E. ×50

tive zone revealed a thick, lamellar structure, which projected to the marrow space as trabeculae (Fig. 12). Microradiographically, the structure of the osteons was more clearly identified in the bone formation zone. The most superficial part of the bone formation zone was also more radiopaque than the bone in the bone formation zone (Fig. 13).

In this group, abnormal structures were also observed in some cases. A thickening of the hyaline cartilage in the hypertrophic zone with irregular masses of chondrocytes and bone tissue was observed at the crest of the condyle in one case (Fig. 14) and on the posterior surface in another case. In one case, abnormal bone resorption and apposition on the surface of the bone plate were seen in the anterior and posterior surface (Fig. 15). In another case, there was a depression of the bone tissue of the bone formation zone at the crest of the condyle (Fig. 16), and resorption of the bone plate on the posterior surface which was covered with fibrous and hyaline cartilaginous tissues (Fig. 17).

The results of the measurement of the articular tissue (from the surface to the junction between the hypertrophic and bone formation zones), subarticular bone plate and osteons in the bone formation zone are shown in Table 1. It appears that the average thickness of the articular tissue in the condyle in the child group was thicker than that of the adult and old age groups but the difference was not statistically significant. Moreover, the variation range was less in the fibrous articular zone than that in the remaining zones of the articular tissue in the majority of specimens. The size of the osteons was approximately the same in all subjects.

Discussion

Regarding the thickness of the articular tissue, Moffett et al. (1964)\(^2\) reported it to be from 0.3 mm to 0.5 mm. The measurement in the present series was done on one sagittal section taken from the mid-point of the condyle and it corresponds nearly to the reported values.

In the histological pictures of the articular tissue of the condyle, as pointed out by Öberg et al. (1971),\(^8\) Wright and Moffett...
Table 1. Thickness of Articular Tissue and Subarticular Bone Plate and Size of Osteons of Subarticular Bone Plate in Mandibular Condyle

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yr.) &amp; Sex</th>
<th>Fibrous articulard zone</th>
<th>Remaining articulard zone of tissue</th>
<th>Total articulard tissue</th>
<th>Subarticular bone plate</th>
<th>Osteon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± S.D. (10^-2 mm)</td>
<td>Range (10^-2 mm)</td>
<td>Mean ± S.D. (10^-2 mm)</td>
<td>Range (10^-2 mm)</td>
<td>Mean ± S.D. (10^-2 mm)</td>
</tr>
<tr>
<td>1</td>
<td>1, F</td>
<td>12 ± 3</td>
<td>7 - 17</td>
<td>24 ± 7</td>
<td>12 - 35</td>
<td>35 ± 6</td>
</tr>
<tr>
<td>2</td>
<td>9, F</td>
<td>16 ± 5</td>
<td>9 - 25</td>
<td>21 ± 10</td>
<td>7 - 38</td>
<td>37 ± 13</td>
</tr>
<tr>
<td>3</td>
<td>15, M</td>
<td>13 ± 3</td>
<td>6 - 17</td>
<td>21 ± 7</td>
<td>10 - 30</td>
<td>34 ± 11</td>
</tr>
<tr>
<td>4</td>
<td>26, F</td>
<td>16 ± 7</td>
<td>10 - 26</td>
<td>17 ± 6</td>
<td>12 - 28</td>
<td>33 ± 17</td>
</tr>
<tr>
<td>5</td>
<td>27, F</td>
<td>10 ± 3</td>
<td>6 - 16</td>
<td>13 ± 8</td>
<td>6 - 30</td>
<td>22 ± 11</td>
</tr>
<tr>
<td>6</td>
<td>27, M</td>
<td>12 ± 3</td>
<td>7 - 16</td>
<td>20 ± 16</td>
<td>11 - 30</td>
<td>31 ± 8</td>
</tr>
<tr>
<td>7</td>
<td>37, M</td>
<td>13 ± 4</td>
<td>10 - 20</td>
<td>13 ± 8</td>
<td>3 - 26</td>
<td>26 ± 11</td>
</tr>
<tr>
<td>8</td>
<td>47, M</td>
<td>16 ± 8</td>
<td>5 - 27</td>
<td>15 ± 7</td>
<td>10 - 25</td>
<td>31 ± 15</td>
</tr>
<tr>
<td>9</td>
<td>47, F</td>
<td>12 ± 5</td>
<td>7 - 26</td>
<td>14 ± 8</td>
<td>3 - 35</td>
<td>21 ± 12</td>
</tr>
<tr>
<td>10</td>
<td>49, F</td>
<td>12 ± 5</td>
<td>6 - 20</td>
<td>22 ± 20</td>
<td>3 - 65</td>
<td>34 ± 23</td>
</tr>
<tr>
<td>11</td>
<td>50, M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>31 ± 8</td>
</tr>
<tr>
<td>12</td>
<td>55, M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27 ± 12</td>
</tr>
<tr>
<td>13</td>
<td>56, F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26 ± 10</td>
</tr>
<tr>
<td>14</td>
<td>57, M</td>
<td>7 ± 4</td>
<td>4 - 16</td>
<td>18 ± 7</td>
<td>4 - 30</td>
<td>21 ± 11</td>
</tr>
<tr>
<td>15</td>
<td>59, M</td>
<td>10 ± 4</td>
<td>6 - 17</td>
<td>13 ± 10</td>
<td>6 - 45</td>
<td>23 ± 12</td>
</tr>
<tr>
<td>16</td>
<td>60, F</td>
<td>15 ± 3</td>
<td>11 - 17</td>
<td>14 ± 8</td>
<td>6 - 26</td>
<td>31 ± 9</td>
</tr>
<tr>
<td>17</td>
<td>61, F</td>
<td>13 ± 3</td>
<td>10 - 17</td>
<td>18 ± 16</td>
<td>8 - 55</td>
<td>32 ± 17</td>
</tr>
<tr>
<td>18</td>
<td>61, M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45 ± 25</td>
</tr>
<tr>
<td>19</td>
<td>63, F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29 ± 5</td>
</tr>
<tr>
<td>20</td>
<td>70, M</td>
<td>13 ± 3</td>
<td>9 - 15</td>
<td>9 ± 5</td>
<td>4 - 17</td>
<td>23 ± 4</td>
</tr>
<tr>
<td>21</td>
<td>70, F</td>
<td>7 ± 3</td>
<td>5 - 12</td>
<td>8 ± 2</td>
<td>4 - 11</td>
<td>15 ± 2</td>
</tr>
</tbody>
</table>

(1974),\(^5\) Mathews and Moffett (1974),\(^9\) and Thilander et al. (1976),\(^6\) there was quite a difference between the child group and the other age groups. However, the articular surface, whether it was the condyle in the child group or the other age groups, was mainly composed of a fibrous tissue and the thickness was not so different. The proliferation zone was narrow in the young adult group and almost disappeared in the adult and old age groups. The hypertrophic zone was made up of the hyalinized fibrocartilage and the chondrocytes were more decreased in number in the adult group. In old age group, the chondrocytes in the hyaline cartilage had almost disappeared. In the bone formation zone, it was found that the bone plate beneath the hyaline cartilage had already formed in the young adult group. Ingervall et al. (1976)\(^7\) also examined the temporomandibular joint microradiographically, the subjects ranging from 1 month to 23 years. They concluded that there were considerable interindividual variations in mineralization and the continuous bony layer around the periphery of the condyle was not fully developed before about the age
of 20. In this study, it was also clearly demonstrated by the microradiogram that the osteons of the subarticular bone plate were less in the young adult group and seemed to increase in number in the old age subjects. Regarding the average size of the osteons, there was no significant difference between each subject. Similar results were found in the human femur and rib studied by Jowsey (1966) and in the human mandibular cortex studied by Manson and Lucas (1962).

In the adult and old age groups, abnormal structures such as thickening or depression in the crest of the condyle, irregular resorption or apposition on the anterior and posterior surfaces of the bone plate were revealed in some individuals.

The remodelling components of the temporomandibular joint has been studied by some investigators. It is generally accepted that the mechanical stress due to the functional activity plays the most important role in joint remodelling. Moffett et al. (1964) and Blackwood (1968, 1966, 1969) described three types of articular remodelling in the human mandibular joint, i.e. progressive, regressive and peripheral types. Blackwood concluded that during the progressive remodelling of the articular tissue the changes take place in the intermediate zone and the fibrocartilage zone while in the covering articular zone there is no alteration or reaction. Then it is possible that the decrease in the vitality or function of the cells of the intermediate zone may be the forerunner of degenerative arthritis. Although there was no case to be considered as degenerative arthritis, the abnormal features in the adult and old age groups of this investigation was assumed probably to be the reactive remodelling against the functional changes of the temporomandibular joint.

ACKNOWLEDGEMENT

The authors wish to thank Mr. Kazuo Kiyono for the preparation of the sections and microradiogram and are also grateful to Miss Shoko Oonuki for her assistance.

REFERENCES


